

Semantic Web Technologies II

SS 2009

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Engineering Ontologies and Semantic Applications

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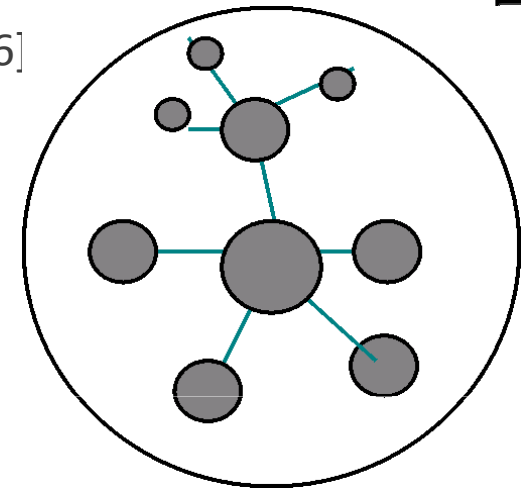
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Topics

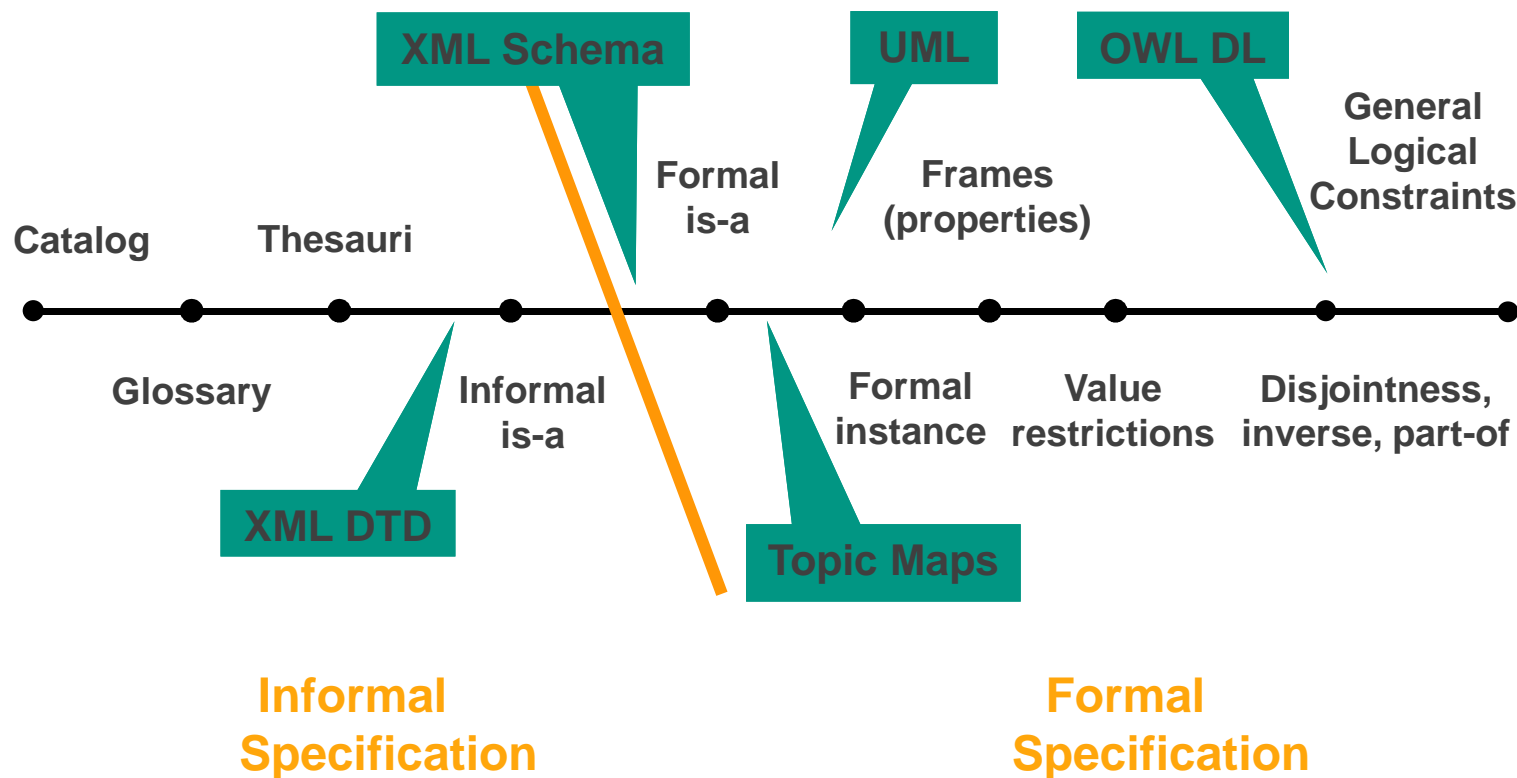
- What are ontologies?
- What are applications of ontologies in semantic applications?
- What are development processes and lifecycle activities for engineering
 - 1) ontologies
 - 2) semantic applications?
- What are supporting infrastructures/architectures for engineering ontologies and semantic applications

Ontologies - Definition

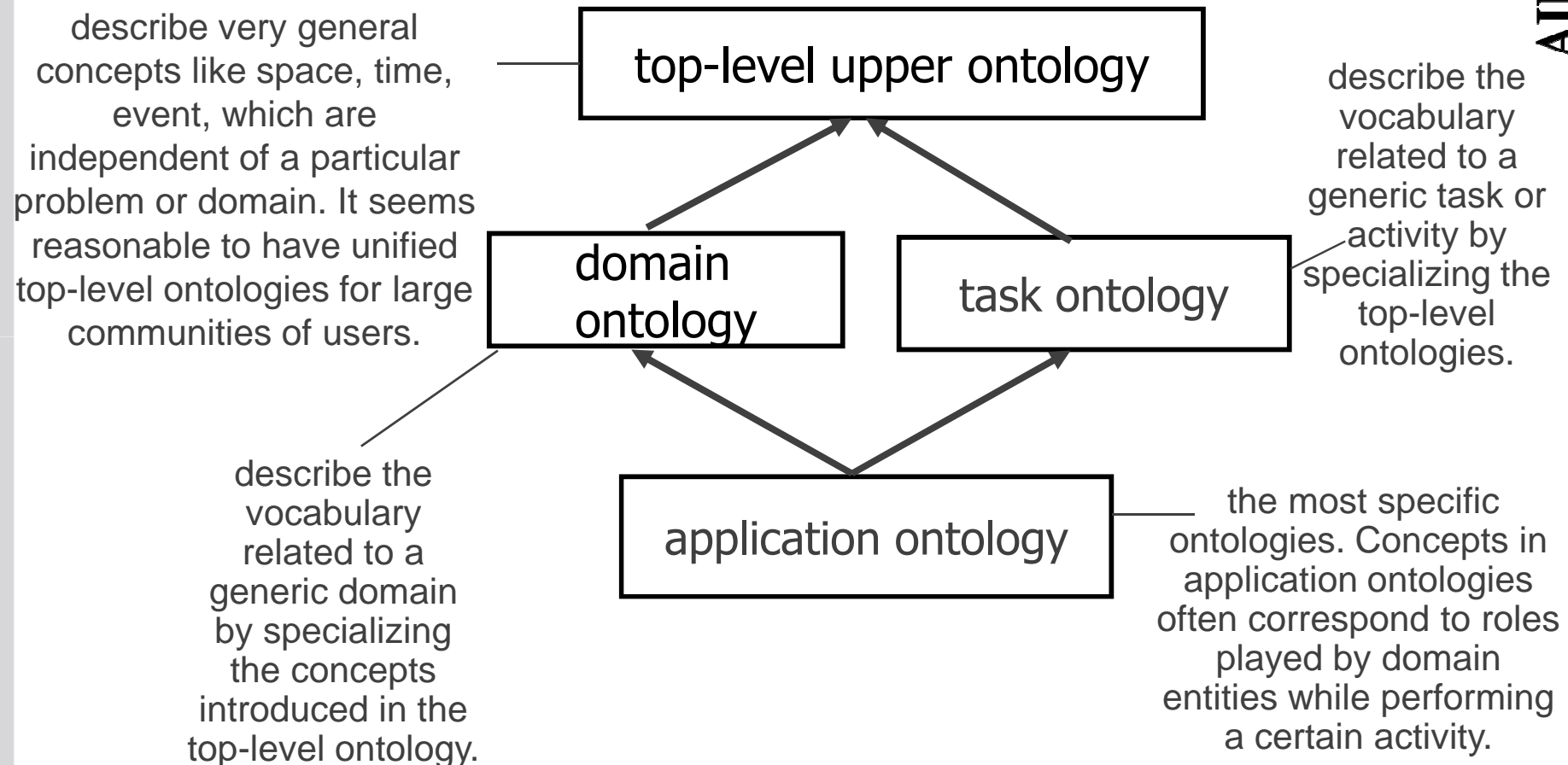
- “An ontology is a **shared understanding** of some **domain of interest**.” [Uschold, Gruninger96]
- “An ontology is an **explicit specification** of a **shared conceptualisation**.” [Gruber93]
- Ontologies
 - Describe a common **vocabulary of terms and their relations**
 - Define the **meaning** of this vocabulary
- Semantics based on **logical languages** guarantees well-defined interpretation
- Can be shared as resources



Varying levels of formality and expressivity



Coverage/Specificity of Ontologies



[Guarino, 98]

Specific ontologies

- Domain-oriented
 - Domain-specific
 - Medicine => cardiology => rhythm disorders
 - Domain generalizations
 - components, organs, documents, gene function
- Task-oriented
 - task specific
 - configuration design, instruction, planning, annotation analysis
 - task generalizations
 - problem solving methods

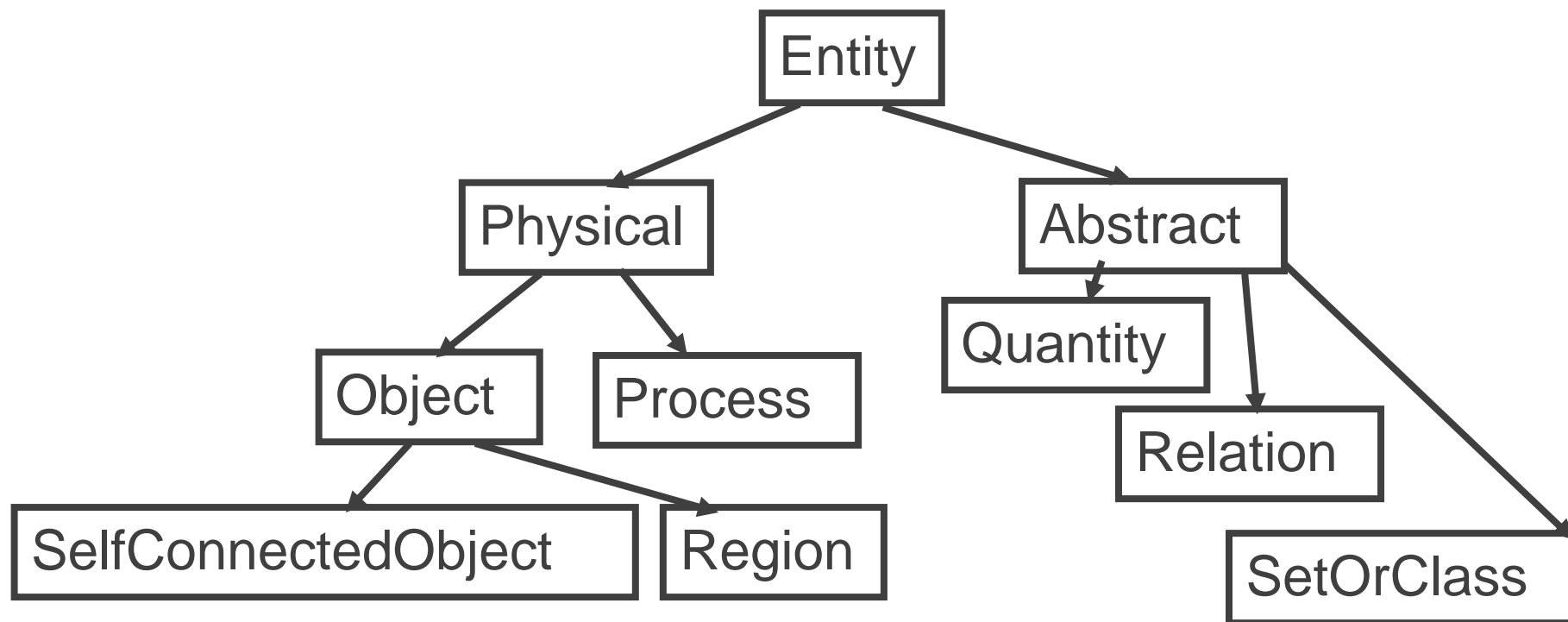
Upper Ontologies

- A.k.a. top level, core, generic or reference
 - An attempt to capture the most general and reusable terms and definitions
 - “Physical”, “Abstract”, “Structure”, “Substance”
 - Useful for ontology re-use
 - Important when generating or analysing natural language expressions
- **Examples of Top Level ontologies**
 - SUMO
 - DOLCE
 - CyC
 - WordNet
 - EuroWordNet

Suggested Upper Merged Ontology (SUMO)

- 1000 terms, 4000 axioms, 750 rules
- Written in FOL
- Development since 2000
- Associated domain ontologies totaling 20,000 terms and 70,000 axioms
- Free
 - SUMO is owned by IEEE but basically public domain
 - Domain ontologies are released under GNU
 - www.ontologyportal.org

SUMO – Top Level Concepts



Cyc

- enCYClopedia
- Douglas Lenat at Cycorp
- Development since 1984
- general knowledge and common-sense reasoning
- Ontology – 100,000's of terms
- Millions of assertions
 - “Water is wet”
 - “Everyone has a mother”
 - “When you let go of things they usually fall.”
- Open version available – opencyc.com

WordNet

- “Lexical ontology”
- 100,000 word senses – synsets
- Created by George Miller's group at Princeton
- Free
- De facto standard in the linguistics world

news item IS A KIND OF ...

1 sense of news item

Sense 1

news item -- (an item in a newspaper)

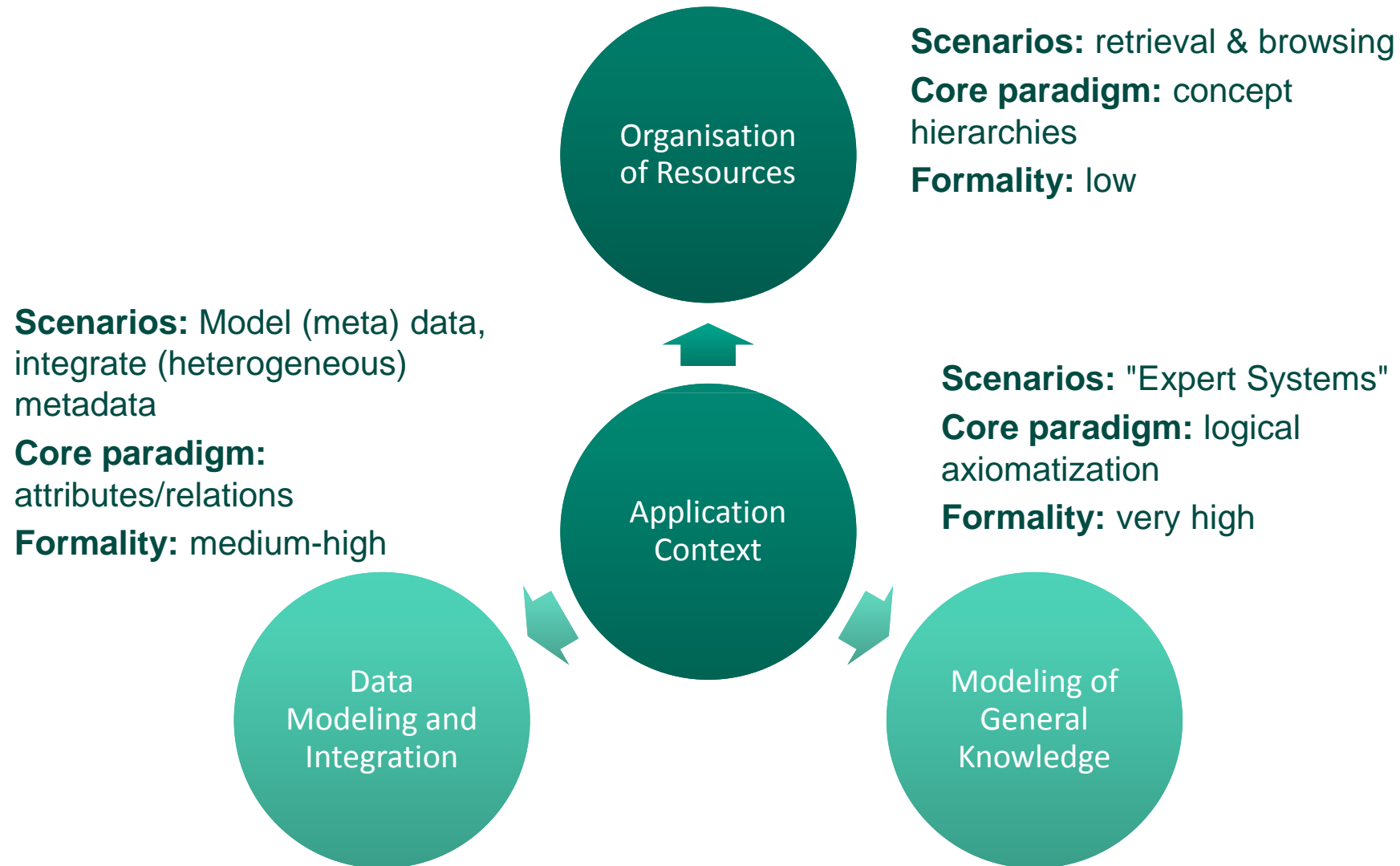
=> **item, point** -- (a distinct part that can be specified separately in a group of things that could be enumerated on a list; "he noticed an item in the New York Times"; "she had several items on her shopping list"; "the main point on the agenda was taken up first")

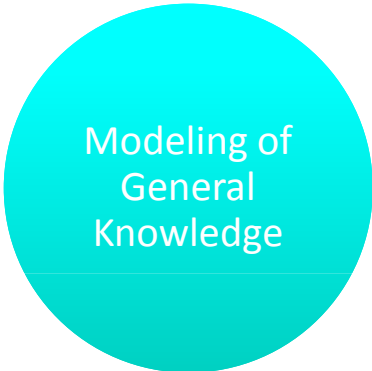
=> **part, portion, component part, component** -- (something determined in relation to something that includes it; "he wanted to feel a part of something bigger than himself"; "I read a portion of the manuscript"; "the smaller component is hard to reach")

=> **relation** -- (an abstraction belonging to or characteristic of two entities or parts together)

=> **abstraction** -- (a general concept formed by extracting common features from specific examples)

Application Context Drives Ontology Design





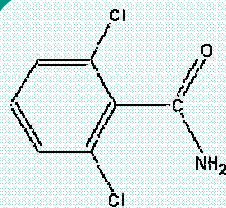
Modeling of
General
Knowledge

APPLICATION SCENARIO: MODELING SCIENTIFIC KNOWLEDGE

Background

Goal:

A "Digital Aristotle" to solve scientific problems



Case study:

Chemistry Knowledge



Project:

HALO – multi phase project
funded by Vulcan Inc



Motivation – Competency Question



- *"Which compounds will produce a gas when HCl is added to the solid compound? HCl is a strong acid producing a yellow-green colored gas above the acid solution?"*

Background

- **The “Digital Aristotle” – a system that:**
 - Encompasses much of the world’s scientific knowledge
 - Reasons over that knowledge
 - Answers novel scientific questions
 - Explains these answers
 - Is quite ambitious
- **The “Digital Aristotle” is a multi-stage effort:**
 - Start with a specific science (Chemistry)
 - Challenge with several teams
 - Answer AP-style questions
 - Refine existing system

Formalizing questions

■ Example

- Which of the following compounds will produce a gas when HCl is added to the solid compound? HCl is a strong acid producing a yellow-green colored gas above the acid solution?

- $\text{Ba}(\text{OH})_2 (\text{s})$
- $\text{CaCO}_3 (\text{s})$
- $\text{CuSO}_4 (\text{s})$
- $\text{Na}_3\text{PO}_4 (\text{s})$
- $\text{NaCl} (\text{s})$

Formalized

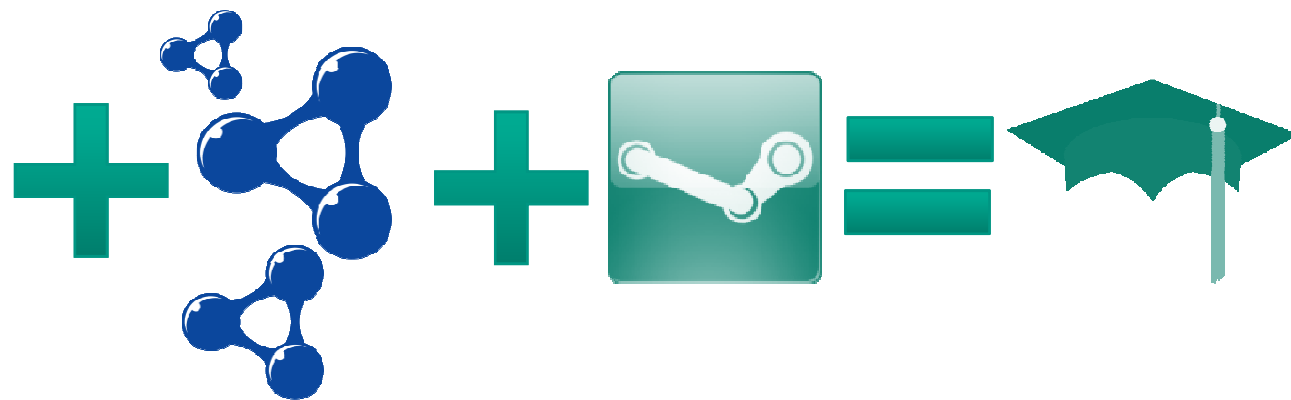
```
(every QF1 has (context ((:pair "(a) Ba(OH)2(s)"  
(a Reaction with (raw-material ((a HCl-Substance)  
(a Ba_OH_2-Substance with (state ((a State-Value  
with (value (*solid)))))))))) (:pair "(b)  
CaCO3(s)" (a Reaction with (raw-material ((a HCl-  
Substance) (a CaCO3-Substance with (state ((a  
State-Value with (value (*solid)))))))))) (:pair  
"(c) CuSO4(s)" (a Reaction with (raw-material ((a  
HCl-Substance) (a CuSO4-Substance with (state ((a  
State-Value with (value (*solid)))))))))) (:pair  
"(d) Na3PO4(s)" (a Reaction with (raw-material  
((a HCl-Substance) (a Ionic-Compound-Substance  
with (state ((a State-Value with (value  
(*solid)))))) (has-basic-structural-unit ((a  
Ionic-Compound with (nested-atomic-chemical-  
formula ((a Chemical-Formula with (term ((:seq  
(:pair 3 Na) (:pair 1 P) (:pair 4  
O)))))))))))))) (:pair "(e) NaCl(s)" (a Reaction  
with (raw-material ((a HCl-Substance) (a NaCl-  
Substance with (state ((a State-Value with (value  
*solid)))))))))) (output ((forall (the context  
of Self) where (oneof2 (the result of (the2 of  
It)) where ((the value of (the state of It2)) =  
*gas)) (the1 of It) (comm [QF1-output-1]  
Self)))))
```

Background Knowledge

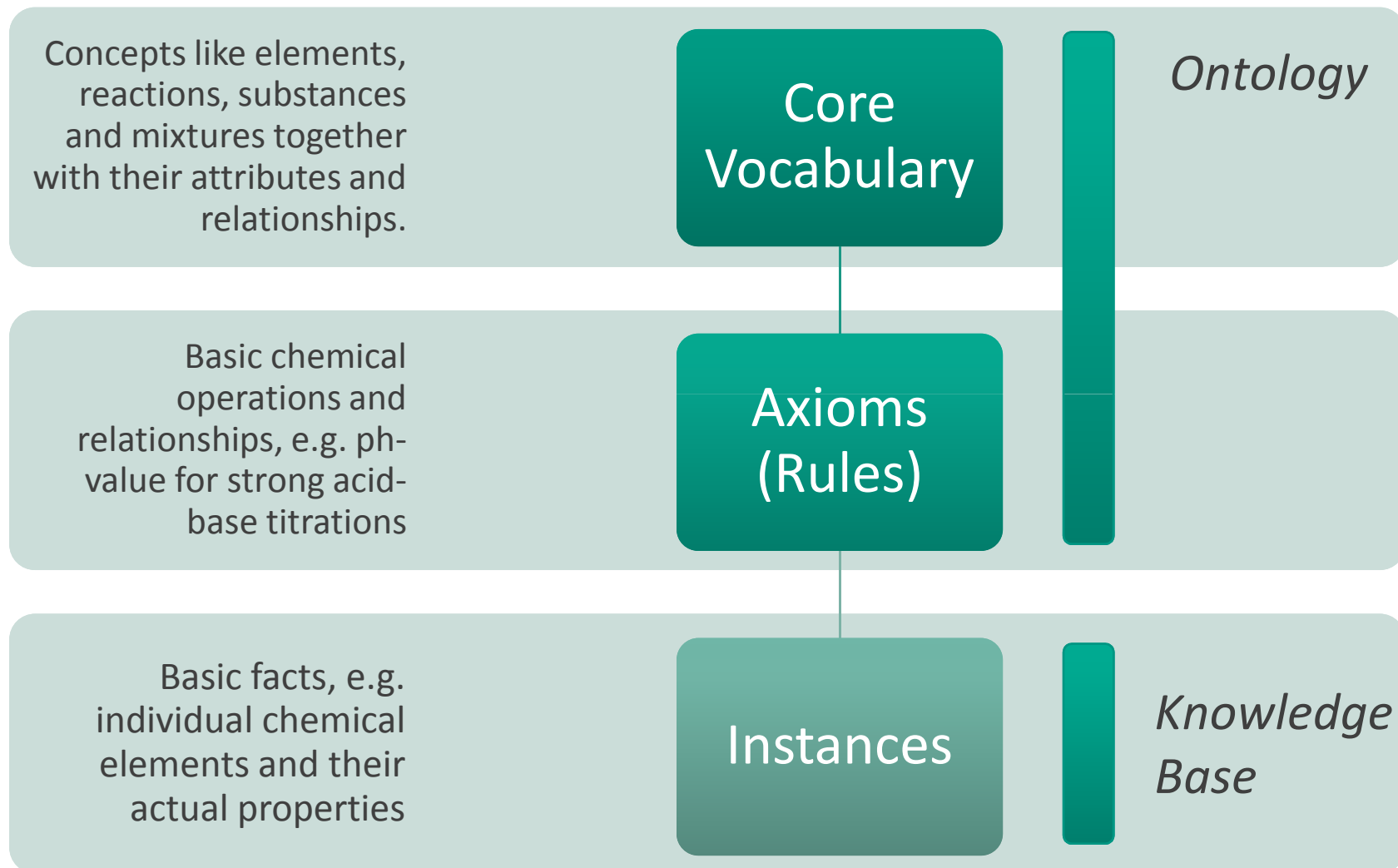
- Formalizing questions is “just” question understanding
- Needs (loads of) background knowledge (ontology)
- Needs a reasoning engine to answer the question using the ontology

```
(every QF1 has (context
  (:pair "(a) Ba(OH)2(s)"
    (a Reaction with (raw-
      material ((a HCl-
        Substance) (a Ba_OH_2-
          Substance with (state
            ((a State-Value with
              (value (*solid))))))))))
  (:pair "(b) CaCO3(s)" (a
    Reaction with (raw-
      material ((a HCl-
        Substance) (a CaO3-
          Substance
```


[...]



Overall Structure



Result browser


CLOSE

QUESTION CHOOSER

MC1 Which of the following compounds will produce a gas when HCl is added to the solid compound? HCl is a strong acid producing a yellow-green colored gas above the acid solution.

MC2 When lithium metal is reacted with nitrogen gas, under proper conditions, the product is:

MC3 Sodium azide is used in air bags to rapidly produce gas to inflate the bag. The products of the decomposition reaction are:

MC4 When calcium carbonate is heated it decomposes forming:

Calcium carbonate reacts with acids to produce gas

MC5 The most likely products for the reaction of NH₃ with oxygen are:

Oxygen is reactive with many chemical compounds while nitrogen gas is very unreactive.

MC6 Which solution has the highest conductivity?

MC7 Which of the following is a non-electrolyte?

MC8 Which of the following combinations would produce a precipitate?

MC9 A solution of nickel nitrate and

BROWSE QUESTIONS: << PREV | NEXT >>

QUESTION MC 1

Which of the following compounds will produce a gas when HCl is added to the solid compound? HCl is a strong acid producing a yellow-green colored gas above the acid solution.

- a. Ba(OH)₂ (s)
- b. CaCO₃ (s)
- c. CuSO₄ (s)
- d. Na₃PO₄(s)
- e. NaCl(s)

CORRECT ANSWER

(b) CaCO₃ (s)

HIDE ANSWER

RESULTS DETAIL

SCORING MATRIX

SME I GRADES
SME II GRADES
SME III GRADES

MORE INFO:

| TEAMS | ENCODING | SME I GRADES | | | SME II GRADES | | | SME III GRADES | | |
|-----------|----------|--------------|---------|------|---------------|-------|------|----------------|-------|------|
| | | ANSWER | JUST. | VIEW | ANSWER | JUST. | VIEW | ANSWER | JUST. | VIEW |
| CYCORP | | 0/1.0 | 0/1.0 | | 0/1.0 | 0/1.0 | | 0/1.0 | 0/1.0 | |
| ONTOPRISE | | 1/1.0 | 0/1.0 | | 1/1.0 | 0/1.0 | | 1/1.0 | 0/1.0 | |
| SRI | | 1/1.0 | 0.5/1.0 | | 1/1.0 | 1/1.0 | | 1/1.0 | 0/1.0 | |

LEGEND: SUBJECT MATTER EXPERTS (SME) QUESTION ENCODING GRADED RESULTS FAILURE DETAIL TIME TO ANSWER

<http://www.projecthalo.com/>

Evaluation

- **General Results**

- **Correctness:** high
- **Justification:** considerably lower than correctness
- **Speed:** was critical, but all systems fared well

- **AP-Test Results**

- Human mean average in this test is AP-2.82
- Project Halo scored an AP-3 – they would have passed!

Refinement Phase

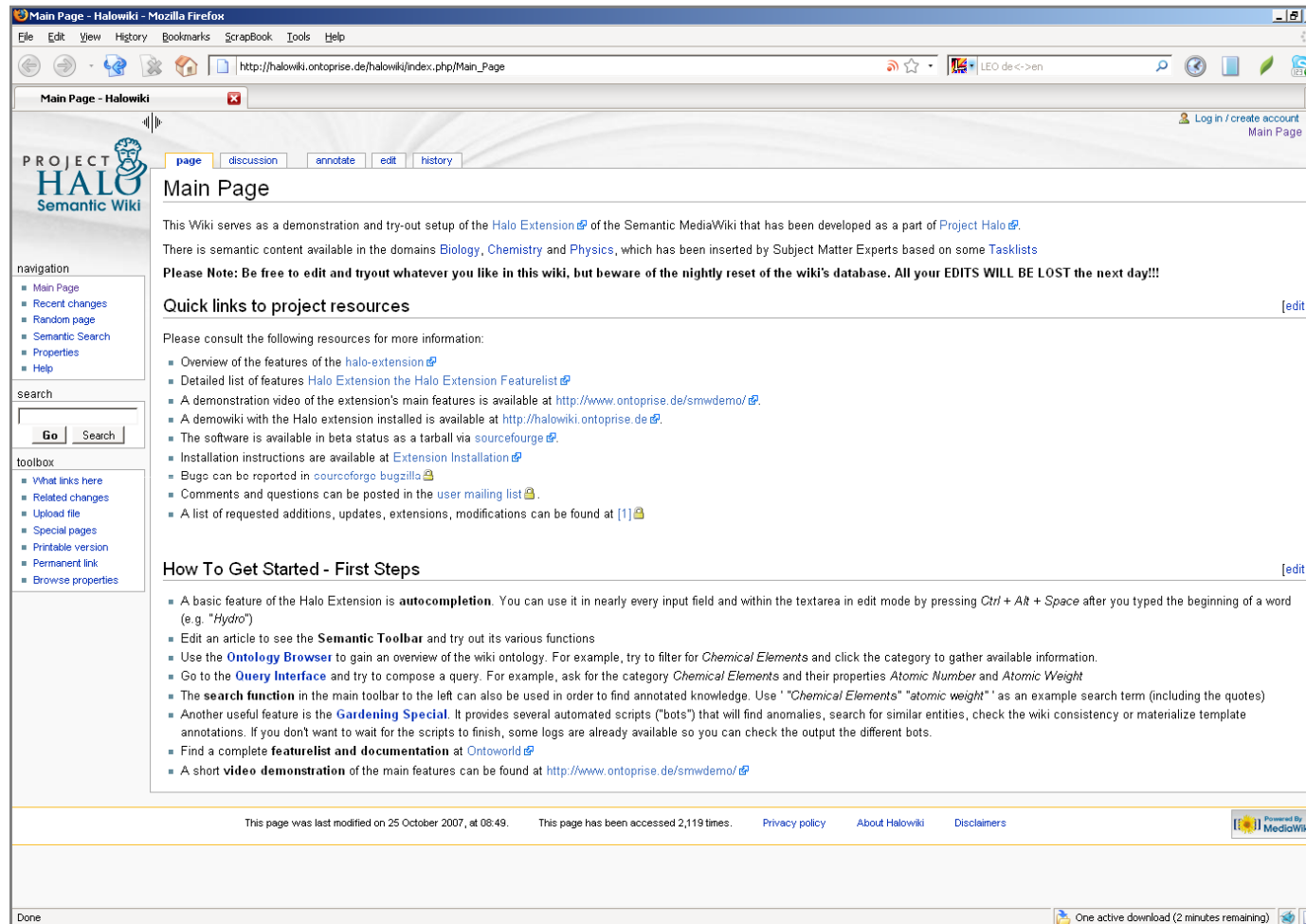
- **Task**

- Gather knowledge faster, cheaper, better...

- **Approach**

- Semantic Wiki for Knowledge Capturing
- As a base, Semantic MediaWiki was taken (open source, developed by AIFB)
- Several enhancements to usability of the system (SMW+, developed by ontoprise)

Knowledge Elicitation via Semantic Wikis



Main Page - Halowiki - Mozilla Firefox

File Edit View History Bookmarks ScrapBook Tools Help

http://halowiki.ontoprise.de/halowiki/index.php/Main_Page

Main Page - Halowiki

Log in / create account
Main Page >

PROJECT HALO
Semantic Wiki

page discussion annotate edit history

Main Page

This Wiki serves as a demonstration and try-out setup of the [Halo Extension](#) of the Semantic MediaWiki that has been developed as a part of [Project Halo](#).

There is semantic content available in the domains [Biology](#), [Chemistry](#) and [Physics](#), which has been inserted by Subject Matter Experts based on some [Tasklists](#).

Please Note: Be free to edit and tryout whatever you like in this wiki, but beware of the nightly reset of the wiki's database. All your EDITS WILL BE LOST the next day!!!

Quick links to project resources

Please consult the following resources for more information:

- Overview of the features of the [halo-extension](#)
- Detailed list of features [Halo Extension the Halo Extension Featurelist](#)
- A demonstration video of the extension's main features is available at <http://www.ontoprise.de/smwdemo/>
- A demowiki with the Halo extension installed is available at <http://halowiki.ontoprise.de>
- The software is available in beta status as a tarball via [sourceforge](#)
- Installation instructions are available at [Extension Installation](#)
- Bugs can be reported in [sourceforge bugzilla](#)
- Comments and questions can be posted in the [user mailing list](#)
- A list of requested additions, updates, extensions, modifications can be found at [\[1\]](#)

How To Get Started - First Steps

- A basic feature of the Halo Extension is **autocompletion**. You can use it in nearly every input field and within the textarea in edit mode by pressing **Ctrl + Alt + Space** after you typed the beginning of a word (e.g. "Hydro")
- Edit an article to see the **Semantic Toolbar** and try out its various functions
- Use the **Ontology Browser** to gain an overview of the wiki ontology. For example, try to filter for *Chemical Elements* and click the category to gather available information.
- Go to the **Query Interface** and try to compose a query. For example, ask for the category *Chemical Elements* and their properties *Atomic Number* and *Atomic Weight*
- The **search function** in the main toolbar to the left can also be used in order to find annotated knowledge. Use "Chemical Elements" "atomic weight" as an example search term (including the quotes)
- Another useful feature is the **Gardening Special**. It provides several automated scripts ("bots") that will find anomalies, search for similar entities, check the wiki consistency or materialize template annotations. If you don't want to wait for the scripts to finish, some logs are already available so you can check the output the different bots.
- Find a complete **featurelist and documentation** at [Ontoworld](#)
- A short **video demonstration** of the main features can be found at <http://www.ontoprise.de/smwdemo/>

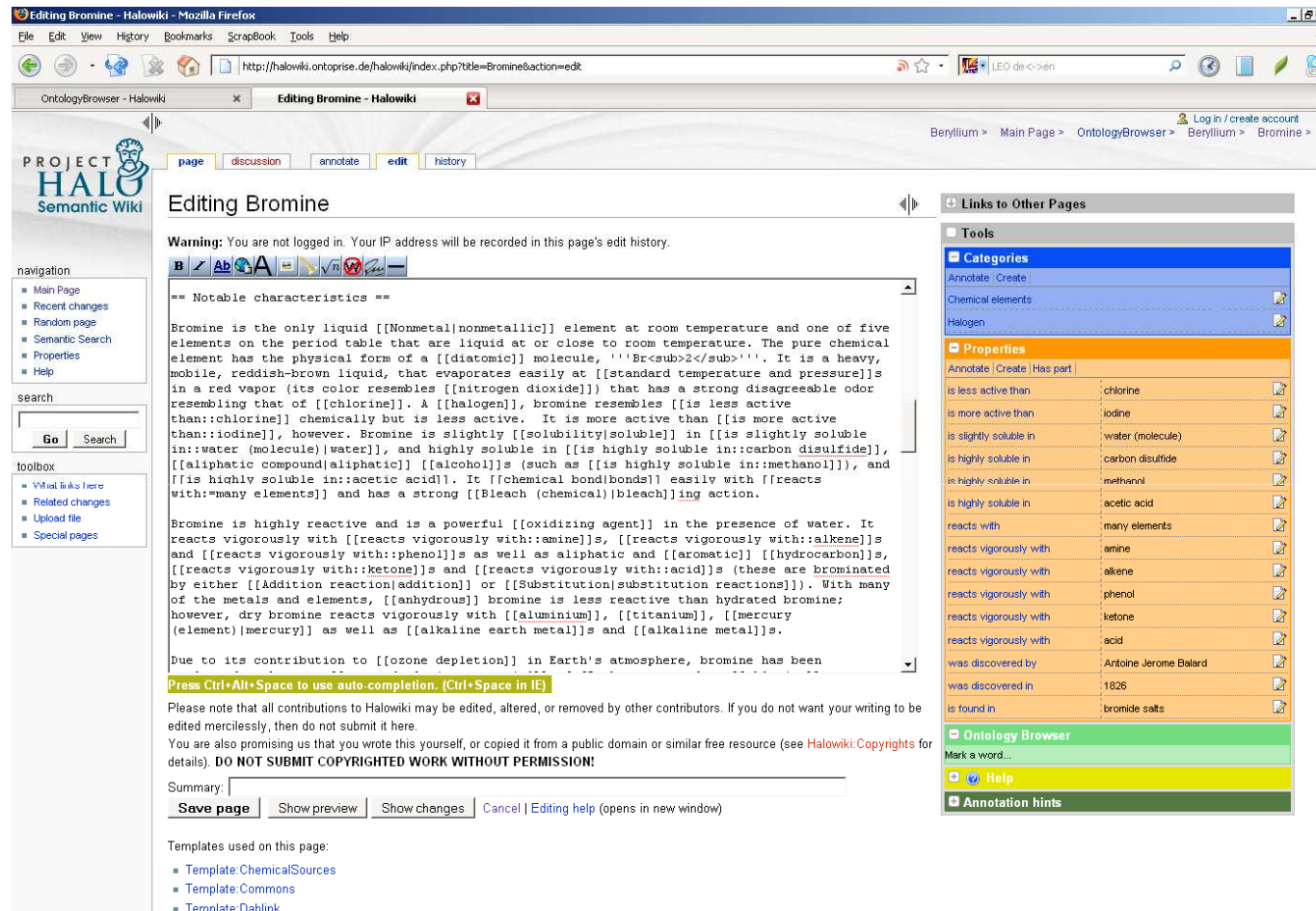
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Knowledge Elicitation via Semantic Wikis



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http://halowiki.ontoprise.de/halowiki/index.php?title=Bromine&action=edit

OntologyBrowser - Halowiki x Editing Bromine - Halowiki

PROJECT HALO Semantic Wiki

page discussion annotate edit history

Beryllium > Main Page > OntologyBrowser > Beryllium > Bromine >

Log in / create account

Editing Bromine

Warning: You are not logged in. Your IP address will be recorded in this page's edit history.

== Notable characteristics ==

Bromine is the only liquid [[Nonmetal|nonmetallic]] element at room temperature and one of five elements on the period table that are liquid at or close to room temperature. The pure chemical element has the physical form of a [[diatomic]] molecule, ''Br₂''. It is a heavy, mobile, reddish-brown liquid, that evaporates easily at [[standard temperature and pressure]]s in a red vapor (its color resembles [[nitrogen dioxide]] that has a strong disagreeable odor resembling that of [[chlorine]]. A [[halogen]], bromine resembles [[is less active than::chlorine]] chemically but is less active. It is more active than [[is more active than::iodine]], however. Bromine is slightly [[solubility|soluble]] in [[is slightly soluble in::water (molecule)|water]], and highly soluble in [[is highly soluble in::carbon disulfide]], [[aliphatic compound|aliphatic]] [[alcohol]]s (such as [[is highly soluble in::methanol]]), and [[is highly soluble in::acetic acid]]. It [[chemical bond|bonds]] easily with [[reacts with::many elements]] and has a strong [[Bleach (chemical)|bleach]]ing action.

Bromine is highly reactive and is a powerful [[oxidizing agent]] in the presence of water. It reacts vigorously with [[reacts vigorously with::amine]]s, [[reacts vigorously with::alkene]]s and [[reacts vigorously with::phenol]]s as well as aliphatic and [[aromatic]] [[hydrocarbon]]s, [[reacts vigorously with::ketone]]s and [[reacts vigorously with::acid]]s (these are brominated by either [[Addition reaction|addition]] or [[Substitution|substitution reactions]]). With many of the metals and elements, [[anhydrous]] bromine is less reactive than hydrated bromine; however, dry bromine reacts vigorously with [[aluminium]], [[titanium]], [[mercury (element)|mercury]] as well as [[alkaline earth metal]]s and [[alkaline metal]]s.

Due to its contribution to [[ozone depletion]] in Earth's atmosphere, bromine has been

Press Ctrl+Alt+Space to use auto-completion. (Ctrl+Space in IE)

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Summary:

Save page Show preview Show changes Cancel | [Editing help](#) (opens in new window)

Templates used on this page:

- Template:ChemicalSources
- Template:Commons
- Template:Dablink

Links to Other Pages

Tools

Categories

Annotate Create

Chemical elements

Halogen

Properties

Annotate Create Has part

| | | |
|------------------------|-----------------------|--|
| is less active than | chlorine | |
| is more active than | iodine | |
| is slightly soluble in | water (molecule) | |
| is highly soluble in | carbon disulfide | |
| is highly soluble in | methanol | |
| is highly soluble in | acetic acid | |
| reacts with | many elements | |
| reacts vigorously with | amine | |
| reacts vigorously with | alkene | |
| reacts vigorously with | phenol | |
| reacts vigorously with | ketone | |
| reacts vigorously with | acid | |
| was discovered by | Antoine Jerome Balard | |
| was discovered in | 1826 | |
| is found in | bromide salts | |

Ontology Browser

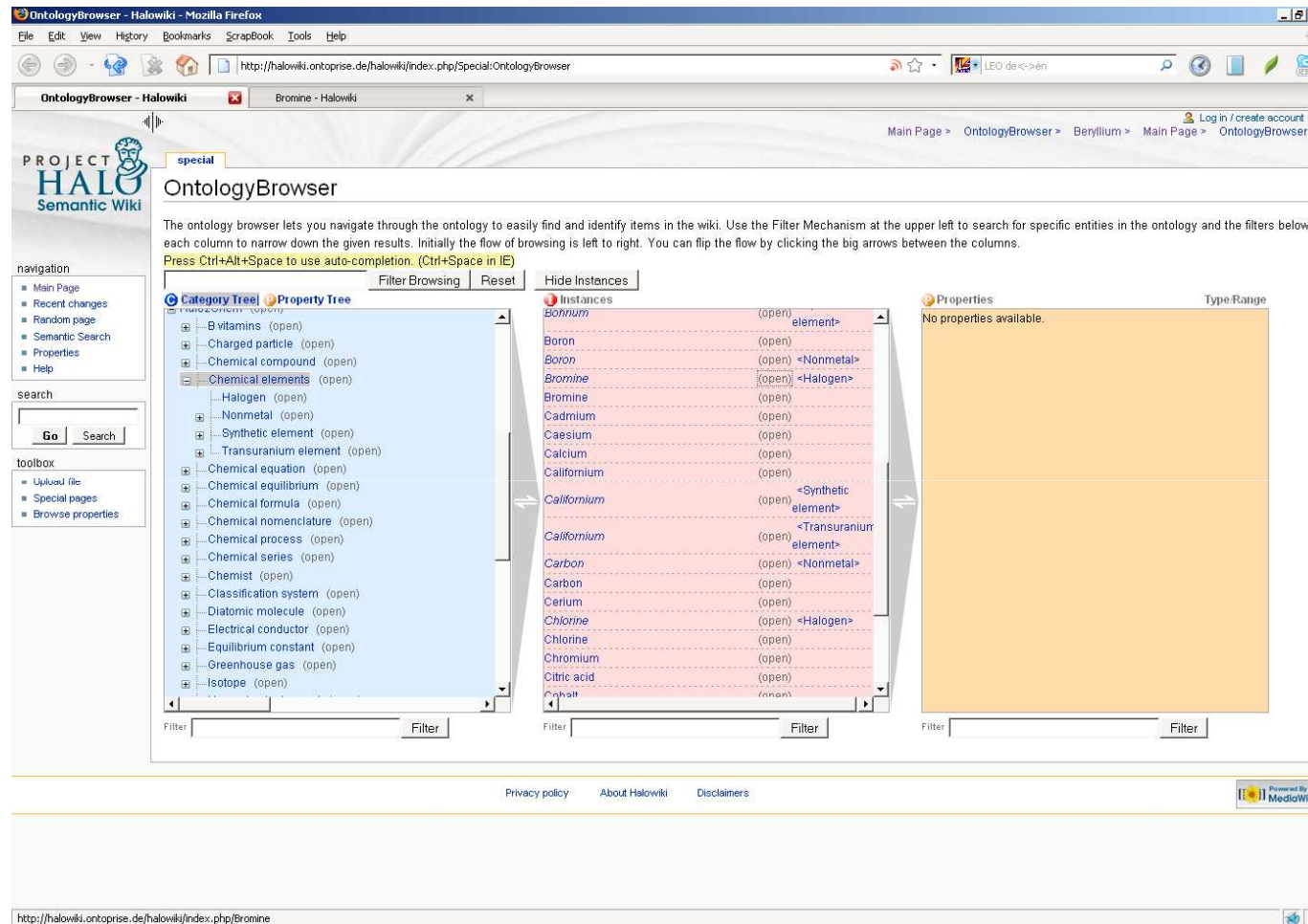
Mark a word...

Help

Annotation hints

<http://halowiki.ontoprise.de/>

Knowledge Elicitation via Semantic Wikis



OntologyBrowser - Halowiki - Mozilla Firefox

File Edit View History Bookmarks ScrapBook Tools Help

http://halowiki.ontoprise.de/halowiki/index.php/Special:OntologyBrowser

OntologyBrowser - Halowiki Bromine - Halowiki

PROJECT HALO Semantic Wiki

special

OntologyBrowser

The ontology browser lets you navigate through the ontology to easily find and identify items in the wiki. Use the Filter Mechanism at the upper left to search for specific entities in the ontology and the filters below each column to narrow down the given results. Initially the flow of browsing is left to right. You can flip the flow by clicking the big arrows between the columns.
Press Ctrl+Alt+Space to use auto-completion. (Ctrl+Space in IE)

navigation

- Main Page
- Recent changes
- Random page
- Semantic Search
- Properties
- Help

search

Go Search

toolbox

- Upload file
- Special pages
- Browse properties

Category Tree Property Tree

Filter Browsing Reset Hide Instances

Instances

| Instances | Properties | Type Range |
|-------------|------------------------|------------|
| Boron | element | |
| Boron | <Nonmetal> | |
| Bromine | <Halogen> | |
| Bromine | | |
| Cadmium | | |
| Caesium | | |
| Calcium | | |
| Californium | | |
| Californium | <Synthetic element> | |
| Californium | <Transuranium element> | |
| Carbon | <Nonmetal> | |
| Carbon | | |
| Cerium | | |
| Chlorine | <Halogen> | |
| Chlorine | | |
| Chromium | | |
| Citric acid | | |
| Citric acid | | |

Properties

No properties available.

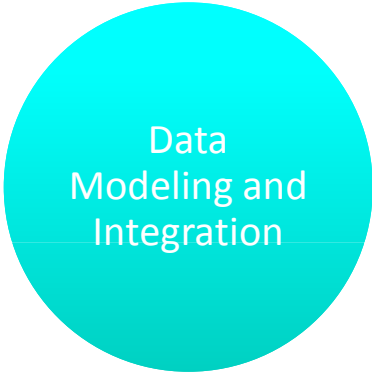
Filter Filter Filter Filter

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http://halowiki.ontoprise.de/halowiki/index.php/Bromine

<http://halowiki.ontoprise.de/>



Data
Modeling and
Integration

SCENARIO: OVERFISHING ALERT SYSTEM

Background

Goal:
Fish Stock Depletion Assessment System
Decision support system to help
Fisheries experts analyzing the status
and trends of world's fish stocks



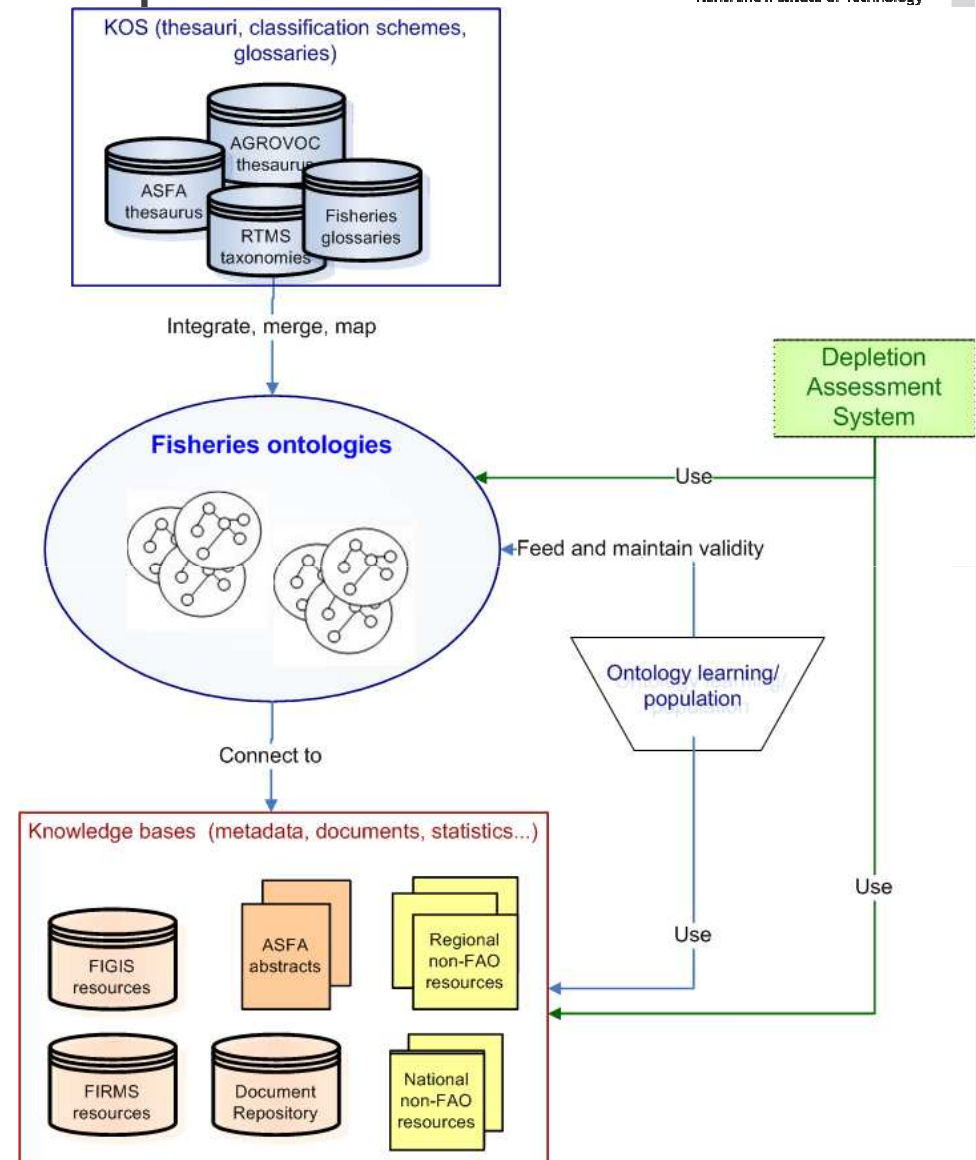
Case study:
FAO - Food and Agriculture
Organization of the United Nations



Project:
NeOn– "Lifecycle Support for
Networked Ontologies"

FSDAS – Ontology Runtime Requirements

- Ubiquitous and easy access to
 - status of fish stock
 - factors affecting fish depletion
- **Integration and querying** of heterogeneous (non-) ontological resources through the exploitation of the Fisheries ontologies
- return relevant results to the client
- Integrate with advanced annotation and visualization tools



Fisheries Lifecycle Management – Ontology Engineering Requirements

- Provide support to ontology engineers and subject experts for:
 - modeling, populating, deploying, versioning ontologies
 - keeping them updated through an editorial workflow
 - managing mappings and relations between them
- Fisheries ontologies are:
 - multilingual ontologies
 - distributed / networked

Ontology Conceptualization

Schema - NeOn Toolkit

File Edit Navigate Search Project Window Help

Ontology Naviga... Entity Properties View

NewOntologyProject

- >species_v1.0.owl
 - Concepts
 - biological_entity
 - family
 - group
 - order
 - species
 - Attributes
 - Relations
 - includesFamily
 - includesOrder
 - includesSpecies

Entity Properties View

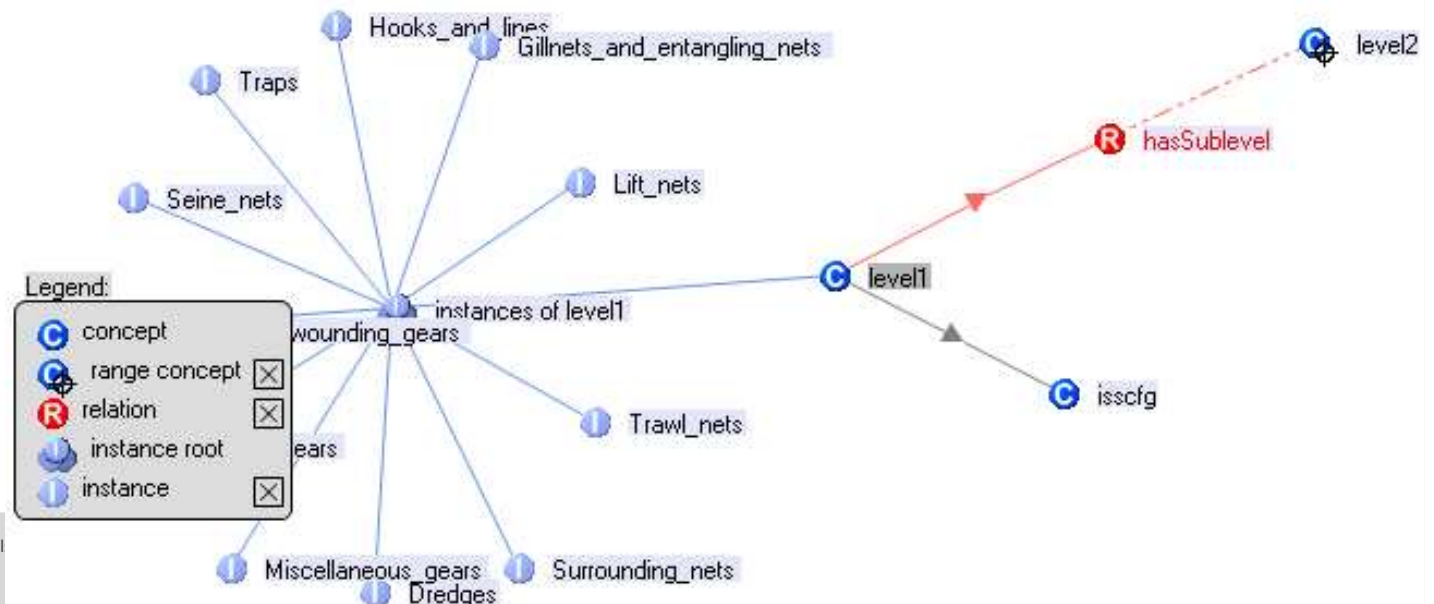
| Relation | Range | Min | Max |
|-----------------|---------|-----|-----|
| includesFamily | family | 0 | N |
| includesOrder | order | 0 | N |
| includesSpecies | species | 0 | N |

Representations

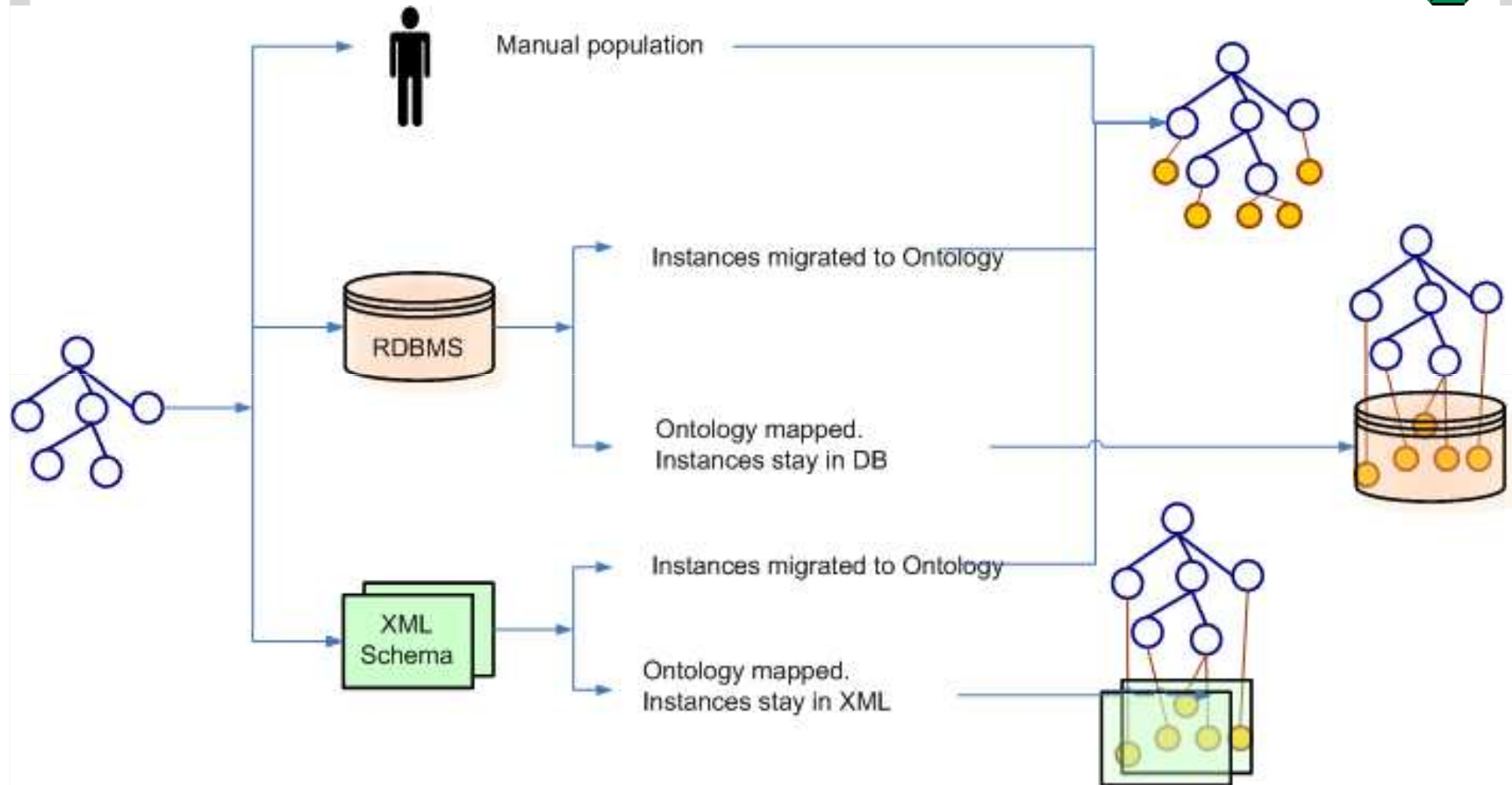
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| | |

Description

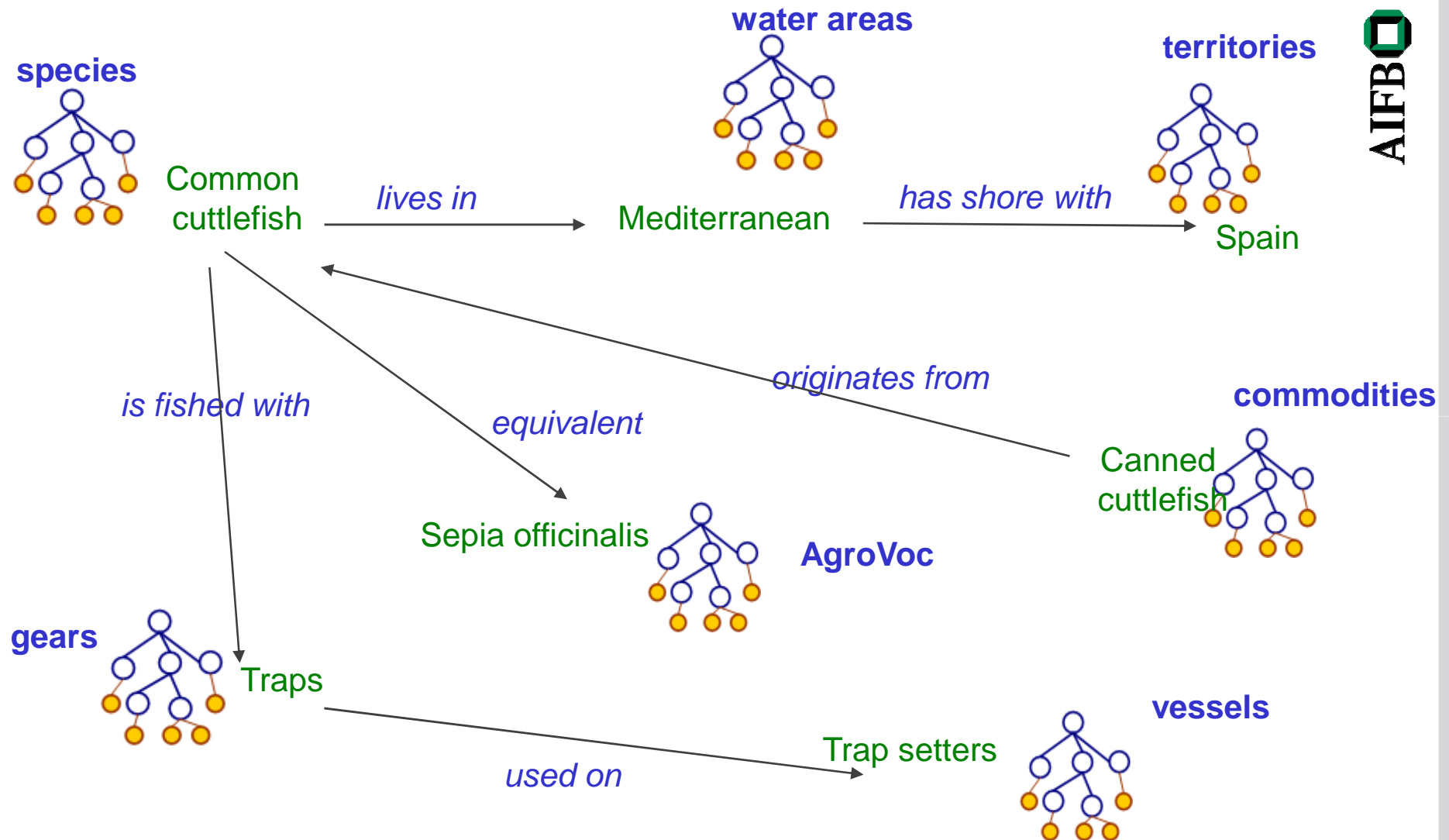
de



Ontology Population



Ontology Mapping to Create a Network



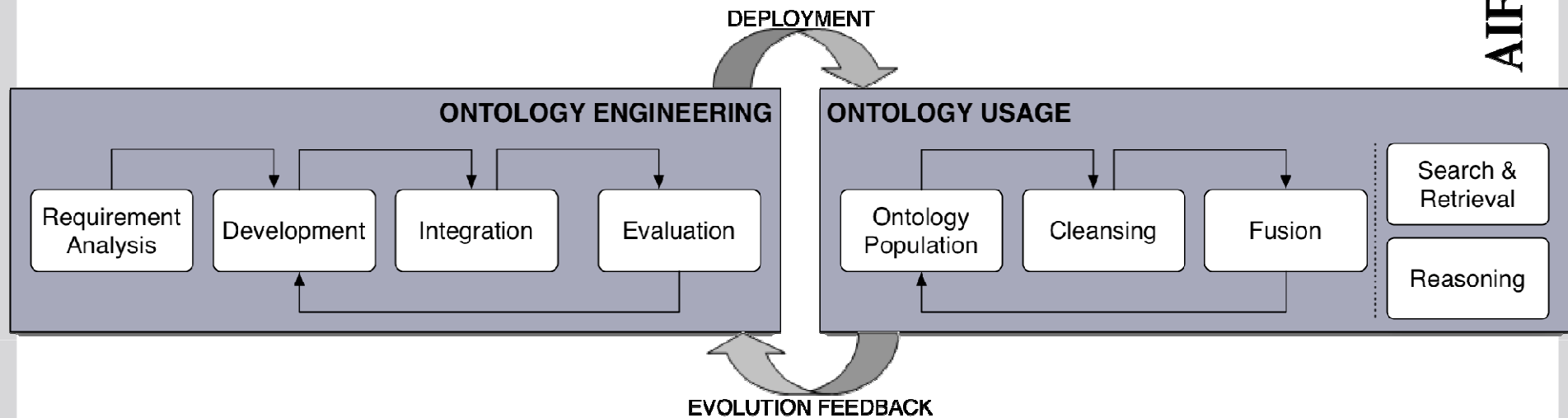
Aspects of Engineering Ontology–based Applications

- Engineering of ontology-based applications is a complex task, which involves
 - Ontology engineering
 - Software engineering
 - **Ontology management throughout the entire lifecycle**

➤ *Require systematic approach to*

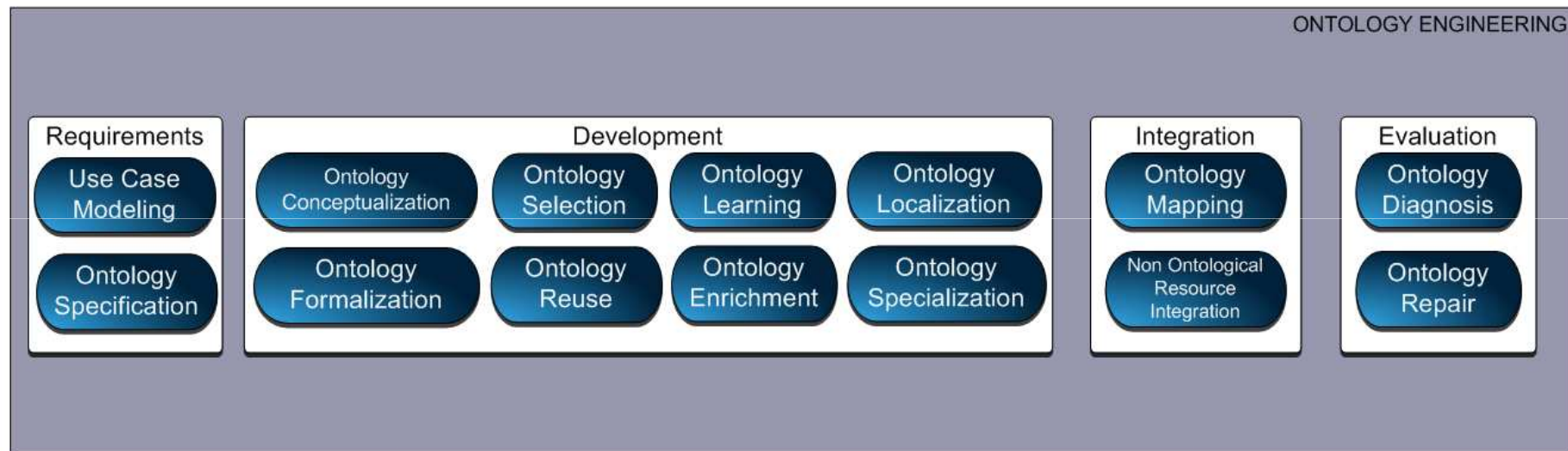
- the ontology and application development process,
- the ontology life cycle,
- the methods and methodologies for building ontologies and applications,
- and tool support

Ontology Lifecycle in Applications



- Close interaction between ontology engineering and runtime usage

Ontology Engineering Activities



How to build an ontology?

Initial Steps

- Requirements specification
- Initial lexicon
- Knowledge extraction

Requirements Specification (I)

- **Domain and Goal**
 - what is the objective
- **Design Guidelines**
 - description of domain in use
- **Supported Applications**
 - brief characteristics of planned application
 - specification of system environment

Requirements Specification (II)

■ Knowledge Sources

- types of knowledge sources may be very different
 - domain experts
 - (reusable) ontologies
 - documents / systems
 - dictionaries
 - thesauri
 - product descriptions
 - organisational charts
 - employee role descriptions
 - ...

Requirements Specification (III)

- **Usage Scenarios** (Users and Use cases)
 - describe users/user groups
 - identify stakeholders
 - describe usage scenarios
 - how do they want to use the system?
 - what kind of support do they expect ?
 - use e.g. UML use-case diagrams
- **Competency Questions**
 - define collection of queries that should be supported by the system
 - analyze queries to find relevant lexical entries (concepts and relations)
 - explore scenarios
 - collect competency questionnaire

Competency Questionnaire

| Competency Questionnaire No. 1 | | | |
|--------------------------------|---|---|-------------------------------|
| Name: | | skill-man-ontology | |
| Date: | | 2001/03/22 | |
| Ontology Engineer: | | T. Model | Domain Expert: X. Pert |
| No. | Competency Question | Lexical Entries | Type |
| Q1 | Which of our consultants has experience with JAVA programming language? | consultant | concept |
| | | consultant <i>is a</i> employee | <i>isA</i> relation |
| | | JAVA | concept |
| | | programming language | concept |
| | | JAVA <i>is a</i> program- ming language | <i>isA</i> relation |
| | | programming language <i>is a</i> skill | <i>isA</i> relation |
| | | employee <i>has experience with</i> skill | relation |
| Q2 | What is the salary of a senior programmer? ... | salary | concept |
| | | ... | |
| Q3 | | | |

Initial lexicon - example

| Competency Questionnaire No. 1 | | | |
|---|---|---|--------------|
| Name: skill-man-ontology Date: 2001/03/22 Ontology Engineer: T. Model Domain Expert: X.Pert | | | |
| No. | Competency Question | Lexical Entries | Type |
| Q1 | Which of our consultants has experience with JAVA programming language? | consultant | concept |
| | | consultant <i>is a</i> employee | isA relation |
| | | JAVA | concept |
| | | programming language | concept |
| | | JAVA <i>is a</i> programming language | isA relation |
| | | programming language <i>is a</i> skill | isA relation |
| | | employee <i>has experience with</i> skill | relation |
| Q2 | What is the salary of a senior programmer? | salary | concept |
| | | ... | |
| Q3 | ... | | |

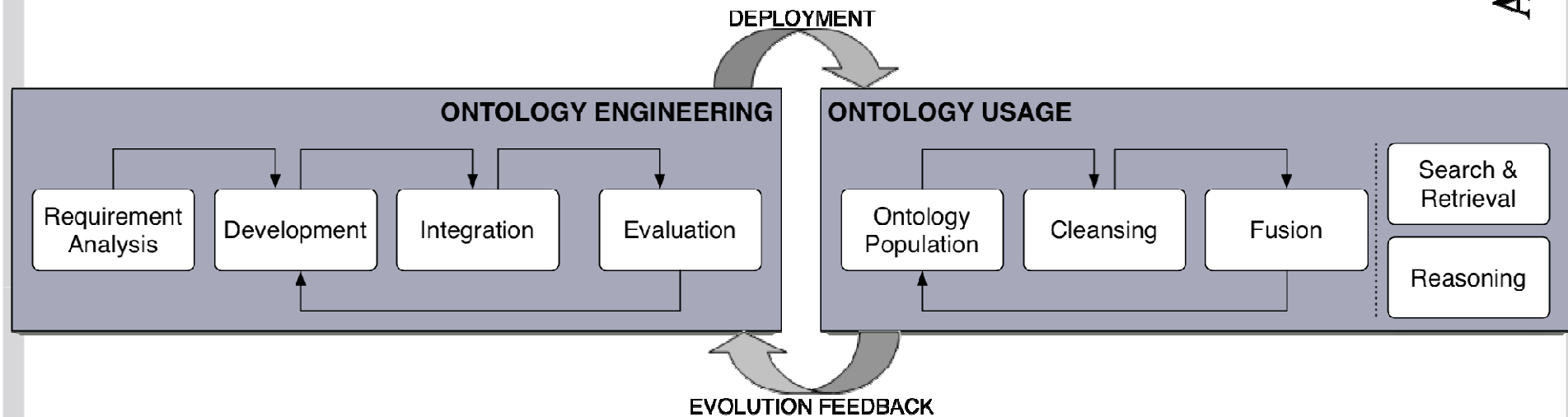
lexical entries

| potential concepts | potential relations |
|---|---|
| Consultant Employee JAVA Programming language Experience Skill Programmer Project Customer Industry ... | HasExperienceWith WorksIn Contains ... |

Knowledge Extraction

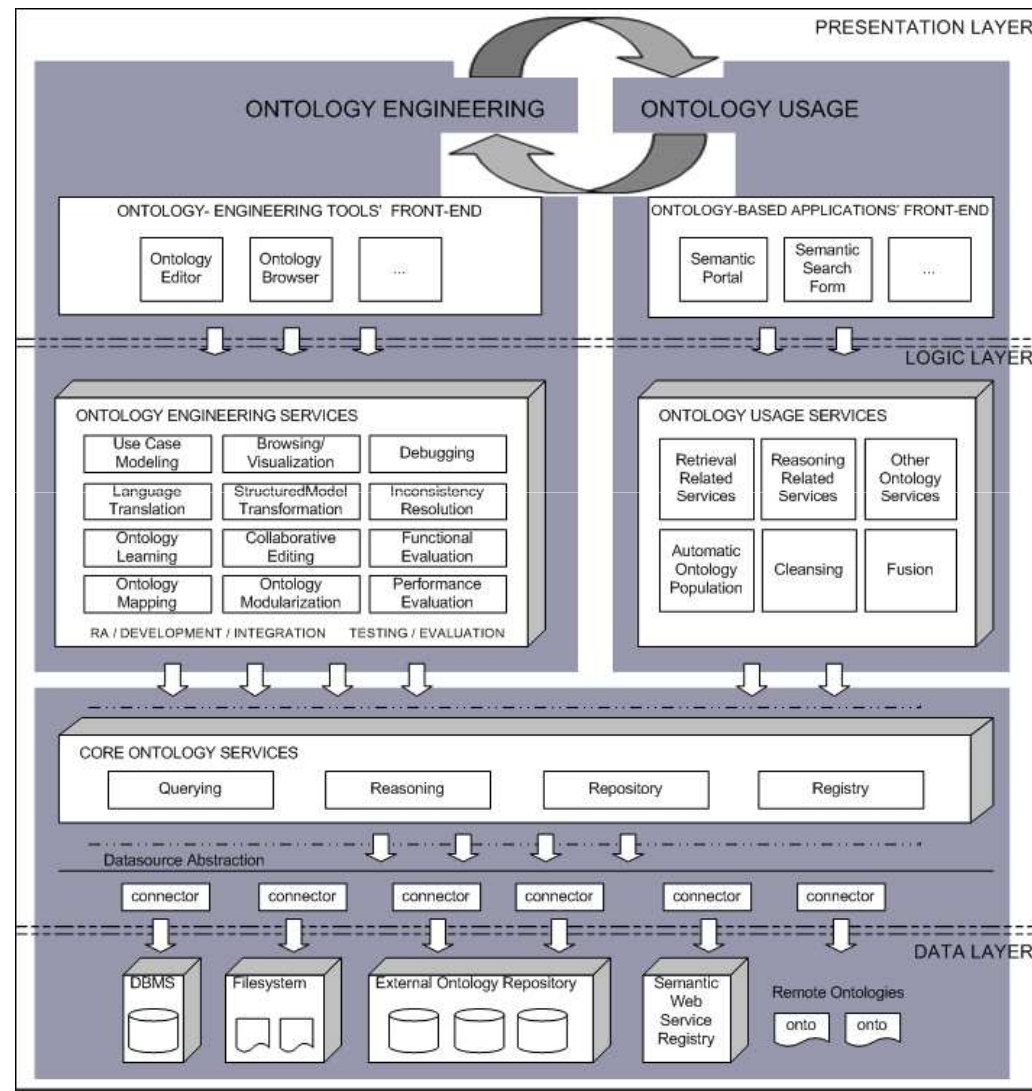
- **top-down** (modeling concepts and relationships on a very generic level)
- **bottom-up** (relevant concepts are extracted semi-automatically from available sources)
- **middle-out** (identify the most important concepts which will then be used to obtain the remainder of the hierarchy by generalization and specialization)

Ontology Lifecycle in Applications



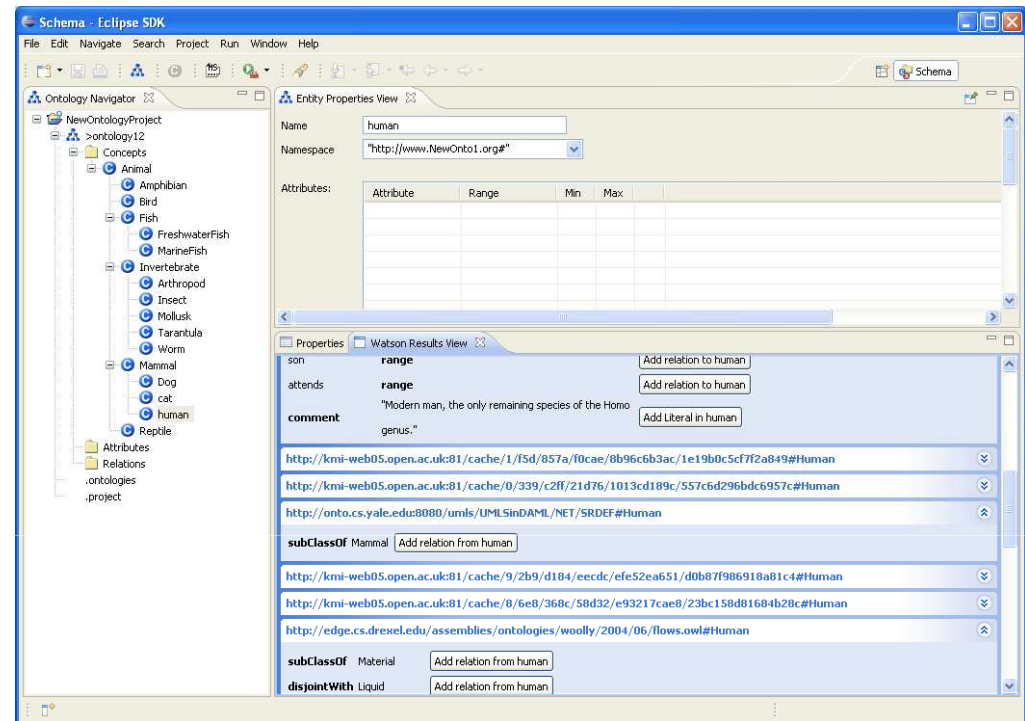
Generic Architecture with Lifecycle Support

- Inspired by SE best practices (SOA, JEE)
- Dynamic interaction of engineering and usage activities
- *Layered Organization*
- Presentation Layer
 - Thin client vs. Rich client
- Logic Layer
 - Business services / objects
 - Ontology services
- Data Layer
 - Ontological sources
 - Non-ontological sources



NeOn Toolkit

- Reference implementation of a generic architecture
- Infrastructure and reusable software components
- Based on Eclipse platform
- Based on a set of standardized APIs
- Plugins support lifecycle activities



<http://www.neon-toolkit.org/>

Summary

- Wide spectrum of types of ontologies
- Wide spectrum of ontology-based applications
 - Organisation of resources
 - Data integration
 - Modeling of generic knowledge
- Methods, methodologies and tools for engineering ontologies and ontology-based applications